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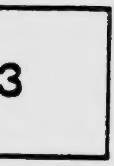

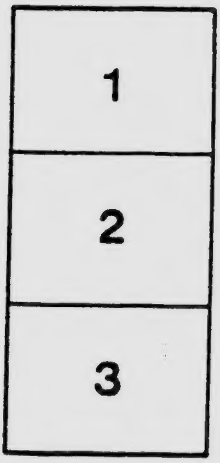

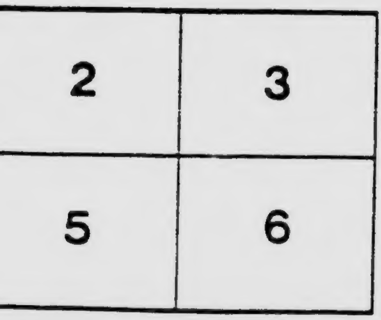

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# PRACTICAL MECHANICS

## FOR SHOP APPRENTICES AND OTHERS

BY JAMES POWELL

Chief Draughtsman, Grand Trunk Railway System
Montreal

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# PREFACE

This work has been written and compiled with the object of laying a foundation and preparing the way for a better education and technical knowledge for apprentices and others in engineering shops, and has been based on what will actually be needed, and should be followed in conjunction with a course of mechanical drawing.

The author, as an apprentice, was connected with mechanics' institutes and technical schools, and for some years was in charge of evening classes, teaching geometrical and mechanical drawing, watching with pleasure the efforts of the young men trying to improve themselves, and guiding them in the direction of their own improvement.

To such as are anxious and willing to learn, I would earnestly plead with them to persevere and not be discouraged.

# PRACTICAL MECHANICS

## For Shop Apprentices and Others

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### ARITHMETIC

*Q. 1.* Multiply 74853926 × 95768.
*Ans.* 7168610785168.

*Q. 2.* Multiply 83653241 × 67589.
*Ans.* 5654038905949

*Q. 3.* Divide 978652 by 652. *Ans.* 1501.

*Q. 4.* Divide 8917622 by 598. *Ans.* 14912.

---

### DECIMALS

*Q. 5.* Add 115.3804, .1100, 23.00, 1.50, and 5.2460
*Ans.* 145.2364.

*Q. 6.* Add 5.50163, 1.05, 761.8, 90.0987601, and .0000304. *Ans.* 858.4504205.

*Q. 7.* Subtract 20.476532 from 22.
*Ans.* 1.523468.

*Q. 8.* **Subtract 891.93542 from 972.85421.**
*Ans.* 80.91879.

*Q. 9.* Multiply .00356 by 1255. *Ans.* 4.46780.

*Q. 10.* Multiply .0125 by .00025. *Ans.* .000003125.

*Q. 11.* Multiply 295.3680 by 125.0062.
*Ans.* 36922.83128160.

*Q. 12.* Divide 673.1489 by .41432. *Ans.* 1624.70.

*Q. 13.* Divide 2.7182818 by 3.1415927 to eight places. *Ans.* .86525595.

*Q. 14.* Divide 16.80437921 by 3.142.
*Ans.* 5.348306.

---

## FRACTIONS.

*Q. 15.* What is the sum of 17, $13\frac{3}{16}$, $\frac{9}{32}$, and $3\frac{1}{4}$?
*Ans.* $33\frac{23}{32}$.

*Q. 16.* What is the sum of $12\frac{3}{4}$, $14\frac{5}{8}$, and $7\frac{5}{16}$?
*Ans.* $34\frac{11}{16}$

*Q. 17.* (1) Subtract $4\frac{7}{16}$ from $9\frac{1}{4}$. *Ans.* $4\frac{13}{16}$.
(2) Subtract $9\frac{15}{32}$ from $17\frac{9}{16}$. *Ans.* $8\frac{3}{32}$.
(3) Subtract $8\frac{3}{16}$ from 9. *Ans.* $\frac{13}{16}$.
(4) Subtract $9\frac{5}{8}$ from $16\frac{1}{2}$. *Ans.* $6\frac{7}{8}$.

*Q. 18.* (1) Multiply $\frac{3}{4}$ by 4. *Ans.* 3.
(2) What is the product of $\frac{4}{8}$ of $\frac{3}{4}$ of $\frac{16}{32}$? *Ans.* $\frac{3}{16}$.
(3) Multiply $9\frac{3}{4} \times 5\frac{5}{8}$. *Ans.* $54\frac{27}{32}$.

*Q. 19.* (1) Divide 30 by $\frac{6}{8}$. *Ans.* 40.
(2) Divide 24 by $\frac{3}{8}$. *Ans.* 64.
(3) Divide 30 by $\frac{3}{16}$. *Ans.* 160.

---

## MENSURATION

***Formula for circumference of circles = diameter × 3.1416.***

*Q. 20.* Find circumference of a circle 9″ diam. *Ans.* 28.2743″.

*Q. 21.* Find circumference of a circle $8\frac{1}{2}$″ diam. *Ans.* 26.7035″.

***To find area of circles. Formula = diam.$^2$ × .7854.***

*Q. 22.* Find area of a circle 6″ diam. *Ans.* 28.274 sq. ins.

*Q. 23.* Find area of a circle 8½″ diam.
*Ans.* 56.745 sq. in.

*To find area of a rectangle. Formula = base × height.*

*Q. 24.* Find area of a square of 43″ side.
*Ans.* 1849 sq. ins.

*Q. 25.* Find area of rectangle, length 28″, breadth 25″. *Ans.* 700 sq. ins.

***To find area of a triangle. Formula = ½ base × perpendicular height.***

*Q. 26.* Find area of a triangle, base 27″. height 33″. *Ans.* 445.5 sq. ins.

*Q. 27.* Find area of a triangle, base 7.5 ft., height 10.75 ft. *Ans.* 40.3125 sq. ft.

***To find the surface of a cylinder. Formula = (area of two ends) + (length × circum.)***

*Q. 28.* Find the surface of a cylinder 2′ 0″ diam. by 4′ 0″ long. $2'\ 0''^2 \times .7854 \times 2 = 6.2832 + 4'\ 0'' \times 2'\ 0'' \times 3.1416 = 31.4160$ sq. ft. *Ans.*

*To find area of surface of a sphere. Formula* = $S = 3.1416 \times \text{diam}^2$.

*Q. 29.* What is the surface of a sphere whose diameter is 14″? $S = 3.1416 \times 14^2 = 3.1416 \times 14 \times 14 = 615.75$ sq. ins. *Ans.*

One cubic foot of water = 6.232 Imperial gallons or 7.476 U.S. gallons.

One cubic foot of fresh water = 62.32 lbs.
One cubic foot of sea water = 64.00 lbs.

*To find cubic contents of a cylinder. Formula = area of base × height.*

*Q. 30.* How much water would a cylinder of 2′ 0″ diam. × 4′ 0″ long hold? $2'\ 0''^2 \times .7854 = 3.1416$ sq. ft. $3.1416 \times 4 = 12.5664$ cubic ft. One cubic foot of water = 7.476 gallons, therefore $12.5664 \times 7.476$ = quantity of water vessel would hold. *Ans.* 93.9464. U. S. gallons.

*To find the contents of a cube. Formula = length × breadth × depth.*

*Q. 31.* Find how many gallons of water are contained in a tank 4′ 0″ long, 3′ 0″ broad, and 2′ 0″ deep. 24 cubic ft. × 7.476 = 179.42 U. S. gallons. *Ans.*

*To find the volume of a sphere. Formula* $= .5236 \times \text{diam.}^3$.

*Q. 32.* What is the weight of a lead ball 12″ in diameter? A cubic inch of lead weighs .41 lbs. $V = .5236 \times d^3$. $.5236 \times 12 \times 12 \times 12 = 904.78$ cu. ins. = volume of ball. $904.78 \times .41 = 370.96$ lbs. = weight of ball. *Ans.*

*To find the volume of a semi-sphere. Formula* $= \text{diam.}^3 \times .5236 \div 2$.

*Q. 33.* Find how much water a pot 48″ diam. by 24″ deep will hold, its shape being semi-spherical. $4' \, 0''^3 \times .5236 = 64 \times .5236 \div 2$ = cubic contents = 16.75 cu. ft. $16.75 \times 7.476 = 125.26$ U.S. gallons. *Ans.*

*To extract the square root of a number. Example 674541903025.*

```
8       | 67'45'41'90'30'25    |  821.305 Ans.
8       | 64
162     | 345
  2     | 324
1641    | 2141
   1    | 1641
16423   | 50090
    3   | 49269
1642605 | 8213025.
        | 8213025.
```

*Q. 34.* Extract the square root of 4160580062500.

*Ans.* 2039750.

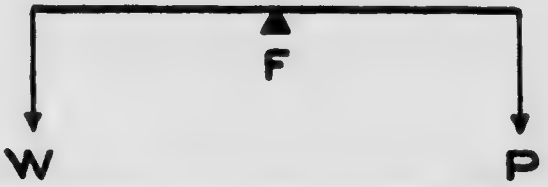
*Q. 35.* Extract the square root of 10588516.

*Ans.* 3254.

# LEVERS

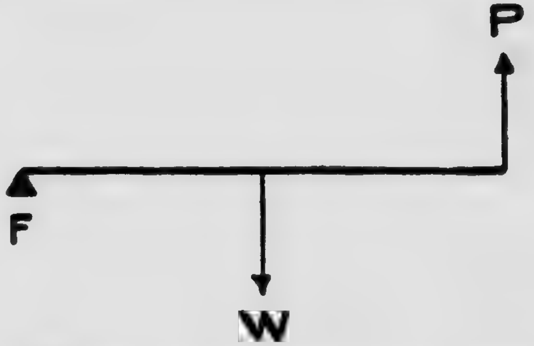
## STYLES OF LEVERS

1.



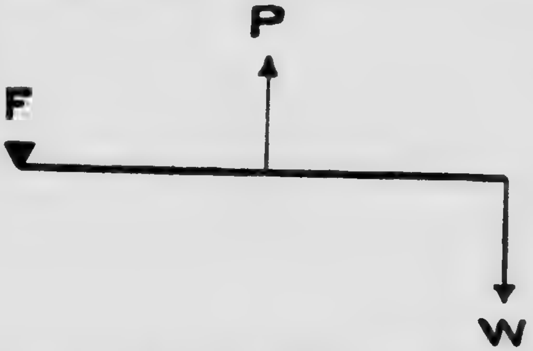
(1) Strain on fulcrum in the first = sum of forces.

2.



(2) Strain on fulcrum in the second = to excess of weight over power.

3.



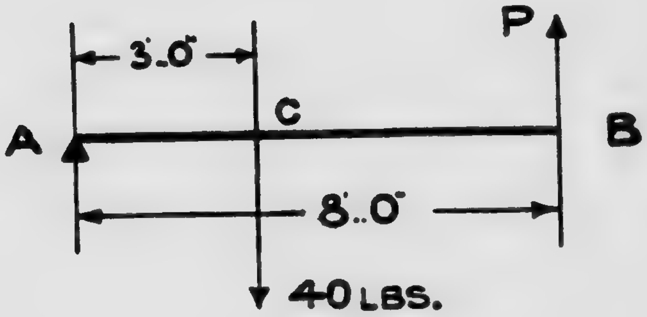
(3) Strain on fulcrum in the third = excess of power over weight.

*Q. 36.* A lever, 54″ long, has a weight 20 lbs. on one end, the fulcrum is 6 inches from the end nearest the weight. Find what force must be exerted to raise it from the ground.

*Ans.* $2\frac{1}{2}$ lbs.

*Q. 37.* A lever A.B., 8′ 0″ long, is supported at A, a weight of 40 lbs. is hung at C, 3 feet from A. What power at B will balance it, and what is the pressure on the fulcrum? $P \times 8' \, 0'' = 40 \times 3' \, 0''$. $P = \frac{40 \times 3}{8} = 15$ lbs. *Ans.*

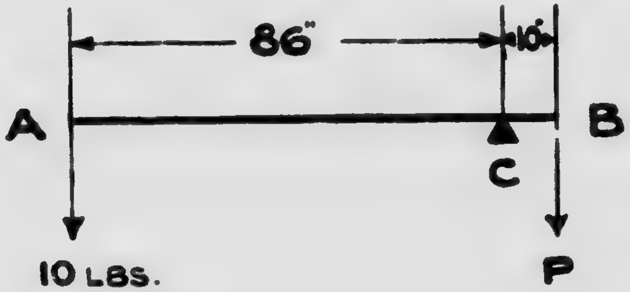
Pressure on fulcrum = 25 lbs. *Ans.*



*Q. 38.* In a lever A.C.B., 8 feet long, the fulcrum C is 10″ from B. What weight is required at B to balance 10 lbs at A?

$$P \times 10 = 10 \times 86 = 860$$

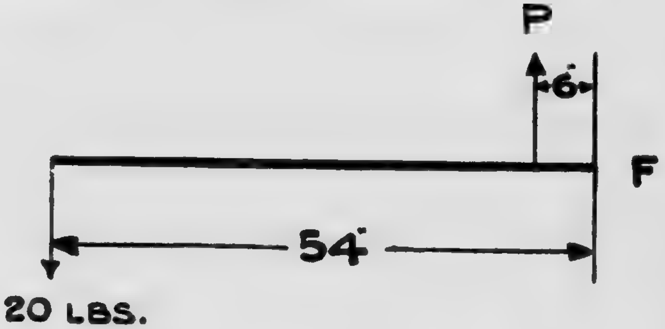
$$\text{Therefore } P = \frac{860}{10} = 86 \text{ lbs.} \quad \textit{Ans.}$$



*Q. 39.* A lever 54" long, fulcrum at one end, 20 lbs. weight at the other end. Find what weight at 6" from fulcrum will balance it.

$$20 \times 54 = P \times 6''$$

$$\text{Therefore } P = \frac{20 \times 54}{6} = 180 \text{ lbs.} \quad \textit{Ans.}$$



*Q. 40.* If the radius of a wheel be 3½ feet, and the radius of the axle 5 inches, what force at the rim of wheel will be required to balance a resistance of one ton at the radius of the axle? 2240 lbs. × 5 ÷ 42 = 266⅔ lbs. *Ans.*

*Q. 41.* A weight of 25 lbs. balances 212 and the radius of the wheel is 28″. Find the radius of axle.

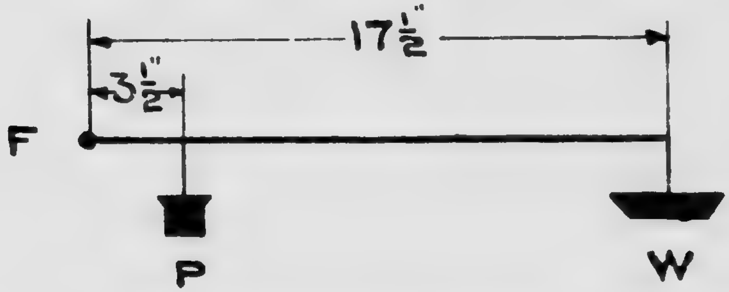
$$\frac{25 \times 28}{212} = 3.3 \text{ inches.} \quad \textit{Ans.}$$

*Q. 42.* Find what weight 27 lbs. would balance in a combination of 4 wheels, with 38, 74, 56, and 48 teeth and four pinions with 12, 17, 21, and 10 teeth. Product of all teeth in wheels × by weight 27 lbs. = weight × product of teeth in pinions =

$$7558656 \times 27 = W \times 42840 = \frac{205083712}{42840}$$

= 4763.86 lbs. *Ans.*

*Q. 43.* A safety valve is $2\frac{1}{2}''$ diam. on the steam side, the lever is $17\frac{1}{2}''$ long, and the distance from the fulcrum to the valve is $3\frac{1}{2}''$. What weight should be hung at the end of the lever in order that the steam may blow off at 30 lbs. pressure?



$2.5^2 \times .7854 = 4.908750$ = area of valve. $4.908750 \times 30$ lbs. pressure = press. on valve = 147.262500 lbs. $147.262500 \times 3.5 = 515.41875 = W \times 17\frac{1}{2}'' = 515.41875 \div 17.5 = 29.452$ lbs. *Ans.* 29.452 lbs. required at end of lever.

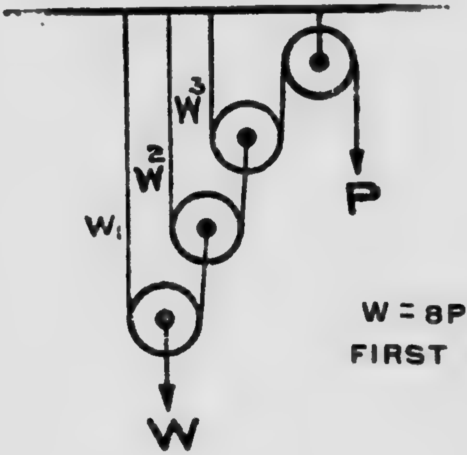
## PULLEYS

*Q. 44.* In the first system, there are three pulleys, the weight to be raised is one cwt., each pulley weighs 2 lbs. Find the value of P, the pull on the end of the rope.

W raises 1″. W1 raises 1″. W2 raises 2″. W3 raises 4″. P raises 8″.

$P \times 8 = (W \times 1) + (W1 \times 1) + (W2 \times 2) + (W3 \times 4).$

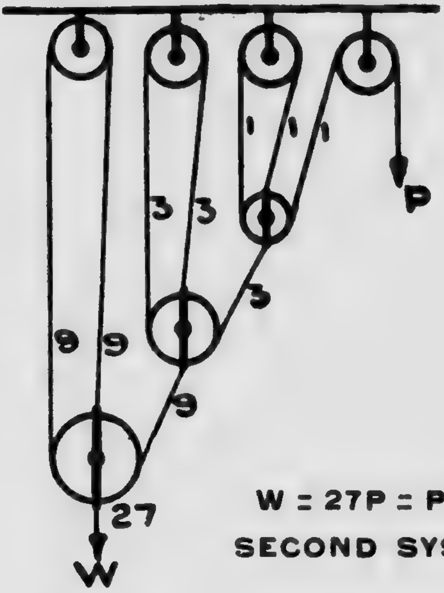
$P \times 8 = (112 \times 1) + (2 \times 1) + (2 \times 2) + (2 \times 4) = 15.75$ lbs. *Ans.*



W = 8P = P × $2^n$
FIRST SYSTEM

*Q. 45.* In the second system, what weight will be supported by 3 cwt., with 4 pulleys?

*Ans.* 243 cwt.

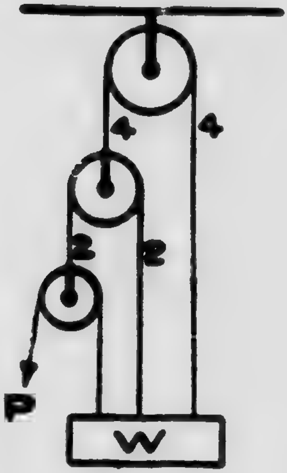


W = 27P = P x 3ⁿ
SECOND SYSTEM

*Q. 46.* (1) In the third system, what weight will a power of 120 lbs. support with three pulleys? *Ans.* 840 lbs.

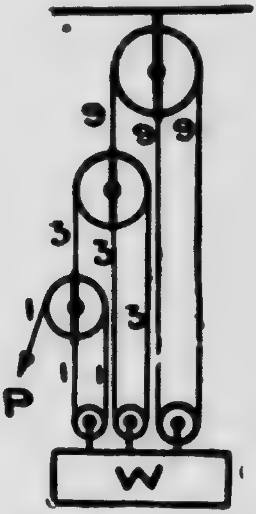
(2) In the fourth system, what weight will be supported by 25 lbs. with 7 pulleys?

*Ans.* 54650 lbs.



$W = 7P = P \times (2^n - 1)$

**THIRD SYSTEM**

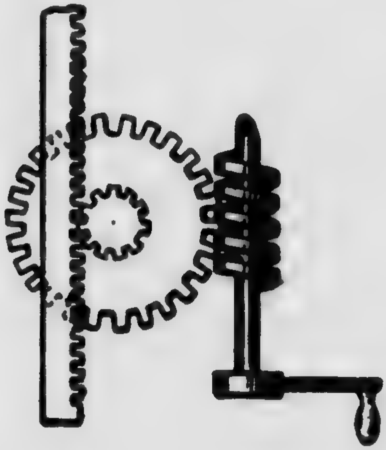


$W = 26P = P \times (3^n - 1)$

**FOURTH SYSTEM**

*Q. 47.* A worm and wheel are used in connection with a rack and pinion to raise the table of a drilling machine, the handle is 12″ long, the worm is single threaded and has 24 teeth, radius of pitch circle of rack 2″, 50% of the work is lost in friction, and the table itself weighs 5 cwt. What weight can be raised by 10 lbs. at the handle? For one revolution of rack pinion the work got out $= W \times 2\pi r$. Work put in $= P \times 2\pi R \times n$. $W \times 2\pi r = P$

$\times 2R \times n$. $W \times 2 = 10 \times 12 \times 24$. $W = 1440$ lbs. without friction less 50% = 720, less 5 cwt. = 160 lbs. net weight raised. *Ans.* 160 lbs.



*Q. 48.* $V$ = velocity of belt, and suppose there is no slipping let $N$ = number of revolutions of driver, and $n$ = number of revolutions of the follower. $V = 2\pi RN = 2\pi rn$. D and d = diams. $DN = dn$.

A pulley of 42″ diameter drives another 18″ diam. at a speed of 250 revolutions per minute. Find the belt velocity and the revolutions of the driver per minute. $V = \pi ND = \pi nd$. $N \times 42 = 250 \times 18$. $N = 107\frac{1}{7}$. $\frac{22}{7} \times \frac{250}{60} \times \frac{18}{12} = 19.6$ feet per second belt velocity. *Ans.*

# UNIFORM MOTION

*Formula for uniform motion* $= S = VT.\ T = \frac{S}{V},$

$V = \frac{S}{T}$, S = space, T = time, V = velocity.

*Q. 49.* The piston speed of a steam engine is 10 feet per second. How many miles will the piston travel in an hour? $S = VT$, $S = 10 \times 60 \times 60 = 6\frac{9}{11}$ miles. *Ans.*

*Q. 50.* A railroad train travels 70 miles in one hour. What is the velocity in feet per second? $V = \frac{S}{T}$ $V = 70 \times \frac{5280}{60 \times 60} = 102\frac{2}{3}$ feet per second. *Ans.*

*Q. 51.* The outside diameter of an engine fly wheel is 13′ 9″, a point on the rim travels 45000 feet in 5 minutes. What is the velocity in feet per second. $V = \frac{S}{T} = \frac{45000}{60 \times 5} =$ 150 ft. per second. *Ans.*

*Q. 52.* If a train moves uniformly at a speed of 40 miles an hour, how many seconds will it take to go 400 ft?

V = 40 miles per hour. S = 400 feet.

$\frac{40 \times 5280}{60 \times 60} = \frac{40 \times 88}{60}$ feet per second.

$T = \frac{S}{V} = \frac{400 \times 60}{40 \times 88} = \frac{600}{88} = \frac{75}{11} =$

$6\frac{9}{11}$ seconds. *Ans.*

*Q. 53.* A body A moves at a rate of 10 ft. per second, and another B, starting from the same place in the opposite direction at 12 ft. per second. Find the distance between them after 10 seconds.

SA = VT = 10 × 10 = 100 ft. SB = 12 × 10 = 120 feet. Distance apart = 100 + 120 = 220 feet. *Ans.*

## CENTRIFUGAL FORCE

*Formula for centrifugal force* = $F = \frac{WV^2}{gr}$ = *lbs.*

When W is weight of body in lbs. V = velocity in feet per sec. g = 32. r = radius of circle in feet. g = gravity.

Example. A locomotive weighs 55 tons and run's around a curve 1200 ft. radius at 20 miles per hour. C.F. or horizontal pressure on rail =

$$\frac{55 \times 2240 \times \frac{88}{3} \times \frac{88}{3}}{32 \times 1200} = 2760 \text{ lbs.}$$ *Ans.*

*Q. 54.* A segment of a fly wheel, with the arm attached, weighs 3500 lbs., and the mean radius is 8 feet from the axis of the wheel. Revolutions 40 per minute. What is the force tending to pull the segment away from the boss of the wheel?

$$C\,F = \frac{WV^2}{gr} = 3500 \times 4 \times \frac{22}{7} \times \frac{22}{7} \times 8 \times 8 \times \frac{2}{3} \times \frac{2}{3} = 15365 \text{ lbs.} \quad V^2 = 4\,\pi^2 r^2 n^2.$$

15365 lbs. *Ans.*

## WORK

*Formula for work. Work = force × space.*

Example. A train weighs 300 tons, the resistance = 10 lbs. per ton. Find work done in drawing it one mile at uniform speed.

F = 300 tons × 10.

S = 1 mile = 5280 feet.

Work = 3000 × 5280 = 15840000 foot lbs.

*Q. 55.* A hole is punched through ½″ steel plate. The pressure necessary is 36 tons. Find work done.

F = 36 tons = 36 × 2240 lbs. S = ½″ = $\frac{1}{24}$ foot = (36 × 2240) × $\frac{1}{24}$ = 3360 foot lbs. *Ans.*

*Q. 56.* A chain hangs from one end 100 feet, weight = 10 lbs. per foot. (1) How much work is done in coiling it on a drum? (2) On raising the lower end to meet the upper?

(1) F = at commencement 100 × 10 = 1000 lbs.

F = at end = O

Therefore, average F =

$$\frac{1000 + 0}{2} = 500$$

$S = 100$ ft. $W = F \times S = 500 \times 100 = 50000$ foot lbs. *Ans.* (1)

(2) F at commencement $= O$

F at end $= \frac{1}{2}$ weight of chain $= 50 \times 10 = 500$

Average force $= \frac{500 + 0}{2} = 250$ $W = F \times S = 250 \times 100 = 25000$ foot lbs. *Ans.* (2)

## WORK AND HORSE POWER

A horse power is the quantity of work, equivalent to the raising of 33000 lbs. through one foot vertically in one minute.

*Formula for horse power.* $H.P. = \frac{F \times S}{T \times 33000}$

*Where* $F \times S =$ *work.*

*Where* $T =$ *time.*

*Q. 57.* An engine raises 10 tons through 20 feet. Find in foot lbs. the work. $W = F \times S = 10 \times 2240 \times 20 = 448000$ lbs. *Ans.*

*Q. 58.* If the engine does the work in two minutes, what is the horse power?

$$\frac{448000}{2} = 224000 \text{ lbs. per min}$$

$$\frac{2240 \times 10}{20} = 1120 \text{ lbs. per ft.}$$

$$W = 1120 \times 20 = 22400 \text{ ft. lbs. per min.}$$

$$\text{H.P.} = \frac{F \times S}{T \times 33000} = \frac{22400}{2 \times 33000} =$$

.33 H.P. approx. *Ans.*

*Q. 59.* Find the useful H.P. of an engine which draws a train of 120 tons on the level at the rate of 40 miles an hour, against a resistance of 18 lbs. per ton. P = pull = 18 lbs. × 120

$$S = \frac{40 \times 5280}{60} = 3520$$

$$\text{H.P.} = \frac{18 \times 120 \times 3520}{33000} = 230.4. \quad \textit{Ans.}$$

Extension of work. Work done = F × S in T (minutes).

$$\text{H.P.} = \frac{\text{work done in foot lbs. per min.}}{33000}$$

*Q. 60.* An express train is running at 40 miles per hour, weight 300 tons, resistance 12 lbs. per ton. What is H.P. exerted?

$$F = 12 \times 300 \text{ lbs.}$$

$$S = \frac{40 \text{ miles} \times 5280}{60} = \text{ft. per min.}$$

$$W. = \frac{12 \times 300 \times 40 \times 5280}{60} = \text{Work done}$$
per minute.

$$H. P. = \frac{W. \text{ per min.}}{33000} = \frac{12 \times 300 \times 40 \times 5280}{60 \times 33000}$$
$= 384$ H.P. *Ans.*

*To find H.P. of a steam engine. Let $A =$ area of piston in square inches, let $P =$ pressure of steam in lbs. per sq. in. $L =$ stroke in feet. $N =$ number of strokes per min.*

$$H.P. = \frac{F \times S}{33000}$$

*$P \times A =$ total pressure on piston.*

*$S = L \times N$. Therefore* $H.P. = \dfrac{P \times L \times A \times N.}{33000}$

*Q. 61.* Find the H.P. of a steam engine, area of piston $= 2$ sq. ft., steam pressure average during stroke $= 100$ lbs., stroke $= 2'\ 6''$, revolutions 110 per min. Steam at both ends of piston.

$$F = P \times A = 100 \times 2 \times 144.$$

$$S = L \times N = 2\tfrac{1}{2} \times 110 \times 2.$$

$$H. P. = \frac{100 \times 2 \times 144 \times 2\frac{1}{2} \times 110 \times 2}{33000} =$$
480. *Ans.*

*Q. 62.* If a body weighing 25 lbs. falls from a height of 100 feet, how much work can be done?

$W = F \times S = 25 \times 100 = 2500$ foot lbs. *Ans.*

*Q. 63.* If the co-efficient is .3, how many H.P. will it require to draw a load of 10,000 lbs. on a level surface a distance of one mile an hour?

$10000 \times .3 = 3000$ lbs. = force necessary to overcome resistance. Resistance of air is neglected. One mile = 5280 feet, one hour = 60 mins.

$$\text{Work} = \frac{F \times S}{T} = \frac{3000 \times 5280}{60} = 264000$$

foot lbs. per min.

$$\text{H. P.} = \frac{264000}{33000} = 8. \quad \textit{Ans.}$$

*Q. 64.* An engine of 4 H.P. is employed to raise a weight of 1 ton. How high will it raise it in five minutes?

Work done per minute = 33000 foot lbs.

Work done in 5 minutes = $5 \times 33000$, but resistance overcome = 2240 lbs. From $W = F \times S$. $S = \frac{W}{F} = \frac{5 \times 33000}{2240} =$ 73.6 ft. *Ans.*

*Kinetic Energy. Formula* $KE = \frac{WV^2}{2g}$

When K E = Kinetic Energy, W = weight of body, V = speed and g = force of gravity.

*Q. 65.* A weight of $\frac{1}{4}$ ton is moving with a velocity of 4 feet per second. What is the work stored up in it?

$$KE = \frac{WV^2}{2g} = \frac{560 \text{ lbs.} \times 4 \times 4}{2 \times 32} = 140$$

foot lbs. *Ans.*

*Q. 66.* The rim of a fly wheel weighs 2 tons, and the velocity of its rim is 30 ft. per second. How many foot tons of work are stored up in it?

$$KE = \frac{WV^2}{2g} = \frac{2 \times 30 \times 30}{2 \times 32} = 28\tfrac{1}{8} \text{ foot}$$

tons. *Ans.*

*Q. 67.* A man wields a 14 lb. hammer and strikes with a velocity of 32 feet per second and 25 blows per minute. At what H.P. does he work?

$$K\,E \text{ per blow} = \frac{WV^2}{2g} = \frac{14 \times 32^2}{2 \times 32} = 14 \times 16$$

$$HP = \frac{14 \times 16 \times 25}{33000} = .17. \quad \textit{Ans.}$$

*Q. 68.* A jet of water is projected against a vertical plane so that 300 gallons strike it per second, its velocity is 80 feet per second. A gallon of water weighs 10 lbs. What is the pressure on the wall?

$$P = \frac{W \times V}{g} = \frac{300 \times 10}{32} = 7500 \text{ lbs.} \quad \textit{Ans.}$$

$W$ = weight of water which strikes plate.

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## PROPERTIES OF MATERIALS

COMPRESSIBILITY is that property by which the volume may be lessened.

EXTENSIBILITY is that property by which the volume may be increased.

DENSITY of a body is the quantity of matter or mass per unit volume.

DUCTILITY is that property by which the material may be drawn. (Compare steel and cast iron.)

RIGIDITY is the resistance to change of shape when acted upon by a force.

ELASTICITY is that power of regaining quickly its original shape and volume after deformation.

PERMANENT SET. An elastic body, if deformed beyond a certain limit, will not recover its original shape, though it may for a small deformation. It is then said to have a permanent set, and this limit is called the limit of elasticity. Limit of elasticity of steel is 12 to 14 tons.

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## WEIGHT OF METALS PER CUBIC INCH

Cast iron = .26 lbs.

Wrought iron = .2777.

Steel = .288.

Brass = .3.

---

*Q. 69.* Find weight of a bar of cast iron 5″ × 6″ × 10′ 0″ long = 78 lbs.

Find weight of a bar of wrought iron 5″ × 6″ × 10′ 0″ long = 83.3 lbs.

Find weight of a bar of steel 5″ × 6″ × 10′ 0″ long = 86.4 lbs.

Find weight of a bar of brass 5″ × 6″ × 10′ 0″ long = 90 lbs. *Ans.*

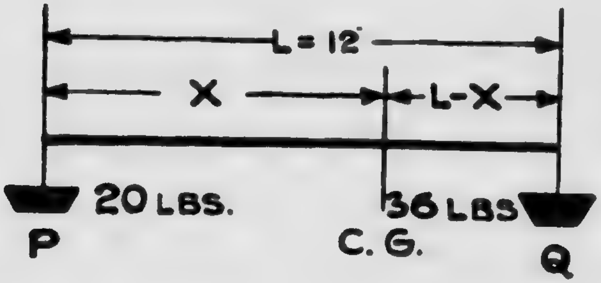
*Q. 70.* Find weight of a W.I. tube 2″ internal diameter 1/16″ thick and 18 feet long. Area of external diameter minus area of internal diameter × 18 = cubical contents. Cubical contents × .2777 for W.I. = weight. (Area of 2⅛ = 3.5466) = (area of 2″ = 3.1416) = .4050 × (18 × 12)
.4050 × 216 × .2777 = 24.371 lbs. weight of tube. *Ans.*

*Q. 71.* Find the weight of a cast iron pipe 6″ diameter, ½″ thick and 5 feet long (area of 6½″—area of 6″) × 5 × 12 = cubical contents. 60 (33.183—28.274) = 294.54. 294.54 × .26 = 76.58 lbs. *Ans.*

*Q. 72.* Find the weight of a square tank, 4′ 0″ square, 2′ 0″ deep × 1″ thick, with a cover 1″ thick, all of cast iron.
Cover = 50 × 50 × 1. Cubic ins. inside = 55296. Cubic inches outside = 65000. Difference = 9704 cu. ins. 9704 × .26 = 2523.04 lbs. *Ans.*

The centre of gravity of a body is that point through which the line of action of the weight of the body always passes. The direction of gravity is towards the centre of the earth. When a body is supported at a point and is in equilibrium, then that point is the centre of gravity. A body cannot have more than one centre of gravity.

*Q. 73.* Find the centre of gravity of 20 lbs. and 36 lbs at a distance of 12 inches, suspended on a rod.



$P \times X = Q \times L - X.$ $X \times P + Q = QL.$ $X = \dfrac{QL}{P + Q} = \dfrac{36 \times 12}{20 + 36} = \dfrac{432}{56} = 7\frac{5}{7}$
$12 - 7\frac{5}{7} = 4\frac{2}{7}''$ from big weight. *Ans.*

A fluid is a body in which there is no resistance to change of shape, nor is there any frictional resistance between the particles. Any pressure communicated to a fluid is transmitted equally in all directions through the fluid. Pressure on a heavy fluid is depending on the depth.

Let $W$ = weight of a cubic foot of water and $A$ = area of cylinder base in square feet. $P$ = pressure = $W\ A\ H$. Let $A$ = 1 sq. ft. $P$ = pressure per square foot = $W\ H$. For fresh water $W = 62\frac{1}{2}$ lbs.

The surface of a plane figure immersed in a heavy fluid. $H =$ depth of centre of gravity of the area. $A =$ area of plate. $P =$ total pressure. $P = W \times A \times H$.

*Q. 74.* A plate is hung in a tank of water. Find total pressure on it. Let $A =$ area of plate in square feet. Let $H =$ depth of centre of gravity. $P = W \times A \times H$. $W = 62\frac{1}{2}$ lbs. Total pressure on plate in lbs. per sq. in. Area of plate = 1 sq. ft. Depth = 1 ft. $P = 62.5 \times 1 \times 1 = 62.5$ lbs. per sq. ft. *Ans.*

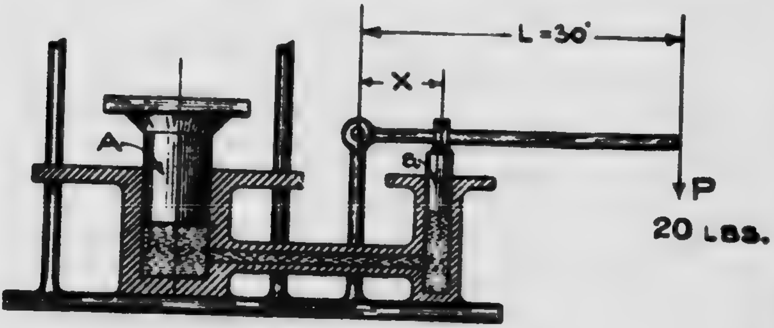
*Q. 75.* A tank is 13 feet square and 4′ 6″ deep. What is the total pressure on one side and also on the bottom of the tank?

The water in the tank is 4′ 6″ deep.

Let $P_1 =$ total pressure on one side $A_1$.

$P_1 = W \times A_1 \times H_1 = 62\frac{1}{2} \times 13 \times 4\frac{1}{2} \times 2\frac{1}{4} = 8226$ lbs. *Ans.*

Total pressure on base $= P_2 \times W \times A_2 \times H_2 = 62\frac{1}{2} \times 13 \times 4\frac{1}{2} = 47531.25$ lbs. *Ans.*



Let W = weight raised at large ram. Also the pressure on large ram.

Let $P_1$ = total pressure at small ram.

$$\left(P_1 \times X = P \times L \text{ then } P_1 = \frac{P \times L}{X}\right)$$

p = intensity of fluid pressure.

$$\left(p = \frac{P_1}{a} = \frac{W}{A}\right) \quad \frac{P \times L}{X \times a} = \text{pressure per square inch} = \frac{W}{A}$$

*Q. 76.* The diameter of the large ram is 8″, of the smaller 2″, the lever arm is 30″ long. From the fulcrum to the small arm 6″. If 20 lbs. be applied at the end of the lever, find the weight that can be raised by the large ram.

$$20 \times 30 = P^1 \times 6 \quad P^1 = 100 \quad p = \frac{100}{a} = \frac{W}{A}$$

$$W = 100 \times \frac{A}{a}$$

$$\frac{100 \times D^2}{d^2} = \frac{100 \times 64}{4} = W = 1600 \text{ lbs.}$$

1600 lbs. *Ans.*

*Q. 77.* The load in the accumulator is 70 tons, the diameter of ram is 8″. What pressure will this give per sq. in?

Let d = sq. ins. in ram. $p \times a = W$

p = lbs. per sq. in.

W = weight on ram.

$$p = \frac{W}{a} = \frac{70 \times 2240}{.7354 \times 8 \times 8} = 3120 \text{ lbs.}$$ *Ans.*

*Q. 78.* A suspended vertical cylinder is tested for tightness of its heads by filling with water. A pipe whose inside diam. is ¼″ and whose length is 20 feet, is screwed into a hole in the upper head and then filled with water. What is the pressure per square inch on each head, if the cylinder is 40″ in diam. and 60 inches long?

Area of heads = $40^2 \times .7854 = 1256.64$ sq. in.

Pressure in bottom head per sq. in., due to weight of water in cylinder = $1 \times 60 \times .03617 = 2.17$ lbs.

$(\frac{1}{4})^2 \times .7854 = .04909$ sq. in. = area of pipe.

.03617 = weight of water per one cubic inch.

$.04909 \times 20 \times 12 \times .03617 = .426$ lbs = weight of water in pipe = the pressure on a surface area of .04909 sq. ins.

The pressure per square inch due to the water in the pipe is $\frac{1 \times .426}{.04909} = 8.68$ lbs. per square inch upon upper head. *Ans.*

*Q. 79.* In the last example, if the pipe is filled with a piston weighing ¼ lb. and a 5 lb. weight is laid upon it, what is the pressure per square inch upon the upper head?

In addition to the pressure of .426 lbs. on the area of .04909 sq. ins., there is now an additional pressure upon this area of $5 + \frac{1}{4} = 5.25$ lbs., and the total pressure upon this area is $.426 + 5.25 = 5.676$ lbs.

The pressure per square inch is $\frac{1 \times 5.676}{.04909} =$ 115.6 lbs. *Ans.*

*Q. 80.* The water level in a city reservoir is 150 feet from the level of the street. What is the pressure per square inch on the hydrant? $1 \times 150 \times 12 \times .03617 = 65.106$ lbs. per square inch. *Ans.* 65.106 lbs.

*Q. 81.* How to find the heating surface of a locomotive boiler.

Example. A boiler has 155 tubes, 2″ external diameter. The length between the tube sheets is 10′ 11″ = (the length of tube available for heating surface). Depth of firebox 5′ 3½″, length of firebox 5′ 7″ by 3′ 0″ broad. Find heating surface.

Take first the tubes (2″ diam. × 3.1416 = circumference) × (10′ 11″ × 12) = area of 1 tube in inches = 6.28319 × 131″ × 155 = heating surface of all the tubes in inches = $\frac{127565}{144} = 885.86$ square feet, heating surface.

Heating surface of crown and side sheets (deduct 6″ at bottom for fire bars). The distance from the bottom of one side sheet over the crown and down the other side = 12′ 4″, 12′ 4″ × length of crown sheet, which is 5′ 7″ = 148″ × 67″ = 9916 sq. inches ÷ by 144 = 68.86 sq. feet. Back sheet area 4′ 7″ × 3′ 0″ broad + 1′ 5″ × 2½ × 2 = 55″ × 36″ + 17 × 2.5″ × 2 = 1980 + 85 = 2065 sq. ins. = 14.34 sq. ft. 14.34 sq ft. − area of fire hole (size of fire hole = 1′ 1¾″ × 1′ 3¾). 176 sq. ins. = 13.11 sq. ft. heating surface of back head. Area of front head = 2065—tube holes = 2065 sq. in.—372 sq. in. = 11.76 sq. ft. (Area of tube holes of 2″ diam. × ⅛″ thick = 1¾″ = area 2.4 × 155 = 372 sq. ins. = 2.58 sq. ft.)

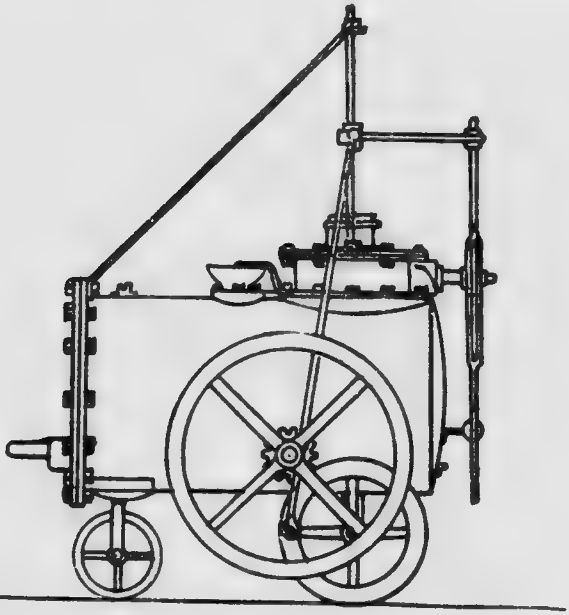
Heating surface of front head = 11.76 sq. ft.
" " " back head = 13.11 sq. ft.
" " " crown and
side sheets = 68.86 sq. ft.
93.73 sq. ft.
= heating surface of firebox.

Heating surface of firebox = 93.73 sq. ft.
" " " tubes = 885.86 " "
Total heating surface 979.59 " "

Grate area = 5′ 7″ × 3′ 0″ = 2412 sq. in. = 16.75 sq. ft.

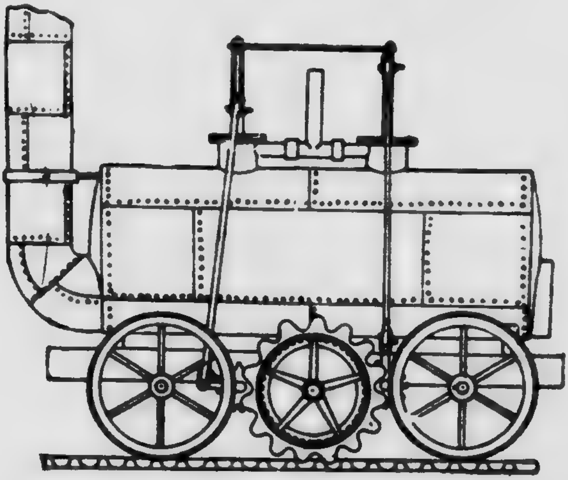
# HISTORY OF THE LOCOMOTIVE

After Watt made his improvements in the steam engine, many thoughtful people began to consider the practicability of turning the new invention to the purpose of locomotion. Watt, though opposed to the scheme, produced improvements in the steam engine which he applied to give motion to wheel carriages. His boiler was to be of wood or thin metal; even earthenware and lead were used in early boilers, as they never dreamed of a pressure much above that of the atmosphere. His fireplace was to be within the cylindrical or globular boiler. Two cylinders were to be used, double acting. Toothed wheels communicated the motion to the axle of the wheels. Trevithick, one of the early pioneers, made



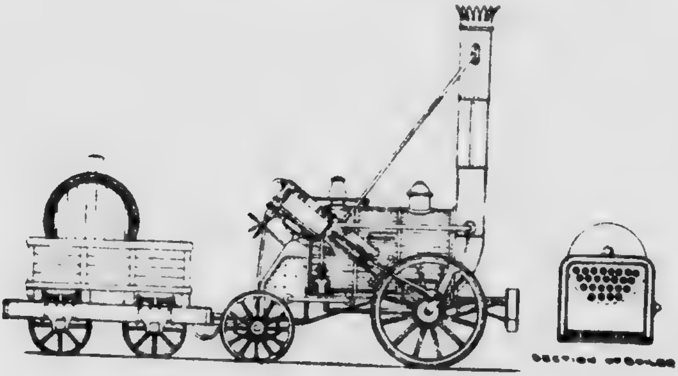
No. 1

and worked the first tramway locomotive. Sketch No. 1 will give an idea of what it was like. The cylinder, standing vertically, is within the cylindrical boiler. The large wheel is a fly wheel, geared on to the shaft. The small hind wheel is the driving wheel, driven by the crank, as seen on the left side of this wheel, the connecting rod coming down from a guide and crosshead above the cylinder. The arrangement for the fire was placed within the boiler. He employed a forced draught, created by steam for working within the chimney. His flue returned from the back through the boiler and the chimney went up by the side of the fire place in front.



No. 2

It was a great difficulty with early locomotive engineers as to how they should secure a proper amount of friction between a smooth rail and a smooth wheel. Hence we find in early locomotive engineering geared wheels working in a rack. It is found that with extremely light weights on the driving wheels that there is not sufficient adhesion and is found useless for any practical purposes. Sketch 2 will show the method used by early engineers to secure adhesion. Sketch 2 represents an engine called Murray's engine, after the maker. The boiler in this case was cylindrical, with ends slightly convexed. It had a single internal flue, with the fire at one end and the chimney coming out at the other. It had two double-acting steam cylinders, the ends of the rods working in guides, while the connecting rods were coupled to cranks, which were made to work at right angles to each other, two on each side of the engine. The cylinders were upright and are seen in the illustration half immersed in the boiler. The cranks drove a toothed wheel on each side of the engine, each of these two wheels geared into another twice the diameter. On the axis of the larger toothed wheel was a coarse pinion (the one seen in the middle front of the figure), which worked in the rack laid along the railway. The rack was a clumsy affair, and the necessity for its use disappeared as

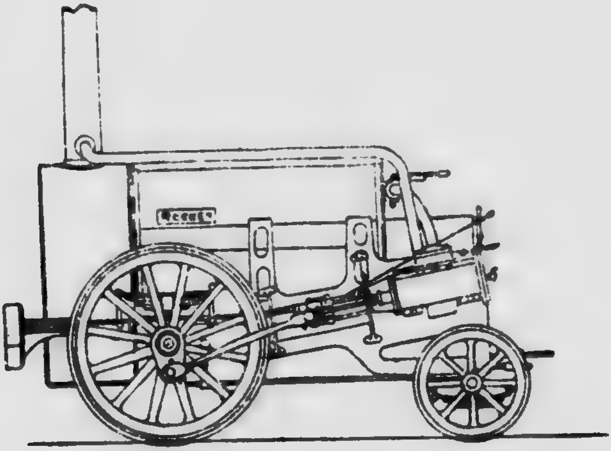


No. 3

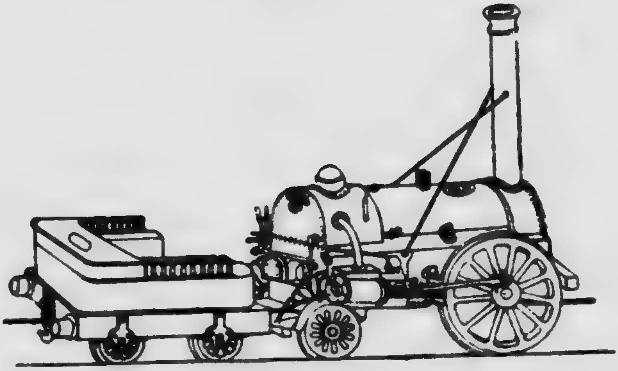
soon as heavier engines were constructed, and it became thoroughly understood that considerable adhesion existed between a smooth loaded wheel and a smooth rail.

In 1829 Stephenson built a locomotive called the "Rocket," shown in sketch 3. It was a four-wheeled engine, supported on springs and with a supply of water in the boiler weighed 4 tons 5 cwt. ; with its tender loaded it weighed 7 tons 9 cwt. Its boiler, of which the accompanying figure is a section, was cylindrical, 6 feet long, with a diameter of 3 feet 4 inches, through it passed 25 copper tubes, 3″ in diameter. These conveyed the heated air and gases and other products of combustion from the firebox to the tall chimney 12″ in diameter at the other end, after passing from end to end of the flue. The firebox or furnace is represented on the left hand side, close to the smaller wheel. It will be noticed that a small tube goes from the boiler barrel to the furnace. This was to allow water to run round the firebox casing: at the top of the firebox was another tube running into the boiler to allow the steam generated in the firebox casing to enter the boiler. The safety valve is the projection on the top of the boiler nearest the chimney. The cylinders were two, one on each side, one is seen to the left, just above the firebox, inclining to the rails at an angle of 45 degrees. This was a poor arrangement, as the pistons slightly lifted the boiler up and down on the springs. It is seen that the connecting rods worked on crank pins on one of the spokes of the driving wheels, and thus the motion of an ordinary connecting rod and crank was gained. The diameter of the cylinder was 8" and the stroke was 16½". The exhaust steam from each cylinder was carried through a pipe and turned upwards into the chimney.

Sketch 4 shows how the "Rocket" was afterwards altered.



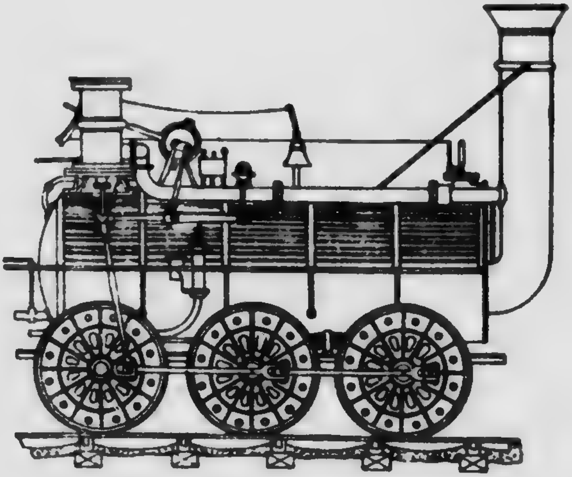
No. 4



No. 5

Sketch 5 shows the "Rocket" as she appeared in 1830, at the opening of the Liverpool and Manchester Railway. As can be seen, a great change was made in the design of the engine. The conclusion arrived at is that the "Rocket" of 1830 was an entirely different engine altogether.

Sketch 6 shows Hackworth's "Royal George," which commenced operations in 1827. The boiler was a plain cylinder, 13 feet long and 4′ 4″ in diameter, a return flue was adopted and a liberal amount of heating surface thus obtained. There were six coupled wheels 4′ 0″ in diameter and the cylinders, which were placed vertically at the end opposite to the fireplace, were 11 inches in diameter, the stroke of the piston being 20″. The piston rods worked downward and were connected to the first pair of wheels. These were without springs, so that the pistons should not jump the wheels up and down, but the middle and back pairs of wheels carried their load through steel springs.



No. 6

In comparison with the modern locomotive there is quite a difference. The cost of a modern locomotive is from $12,000 to $15,000. The "Rocket" cost $2,750. A modern engine weighs (engine and tender), loaded about 323,300 lbs. The weight of the "Rocket" (engine and tender), was 15,008 lbs. The "Rocket's" cylinders were 8" diameter, with a stroke of 16½", diameter of wheels 56½". Cylinders used to-day are 20" diameter by 26" stroke. The boiler of the "Rocket" was cylindrical, with a diameter of 3' 4" by 6 feet long and contained 25 copper tubes. The modern boiler ranges about 25 feet long, with the diameter at the smokebox end 62 inches and with between 200 and 300 tubes, the diameter of wheels of passenger engines being about 73". Diameter of tubes of the "Rocket" was 3", modern engines is about 1¾ inside diameter, made of wrought iron or steel.

This comparison shows what advance has been made in locomotive engineering since the first engine was built. The speed attained by the "Rocket" was 24 miles per hour. The speed attained to-day is from 60 to 70 miles per hour. The boiler pressure of the "Rocket" was 50 lbs. per square inch. A common pressure at the present time is from 200 to 250 lbs. per square inch.

# AREAS AND CIRCUMFERENCES OF CIRCLES

| Diameter Inches | Circumference Inches | Area Sq. Inches | Diameter Inches | Circumference Inches | Area Sq. Inches |
|---|---|---|---|---|---|
| $\frac{1}{16}$ | .19635 | .00307 | 2 | 6.28319 | 3.1416 |
| $\frac{1}{8}$ | .392699 | .01227 | $2\frac{1}{16}$ | 6.47953 | 3.3410 |
| $\frac{3}{16}$ | .589049 | .02761 | $2\frac{1}{8}$ | 6.67588 | 3.5466 |
| $\frac{1}{4}$ | .785398 | .04909 | $2\frac{3}{16}$ | 6.87223 | 3.7583 |
| $\frac{5}{16}$ | .981748 | .07670 | $2\frac{1}{4}$ | 7.06858 | 3.9761 |
| $\frac{3}{8}$ | 1.17810 | .11045 | $2\frac{5}{16}$ | 7.26493 | 4.2000 |
| $\frac{7}{16}$ | 1.37445 | .15033 | $2\frac{3}{8}$ | 7.46128 | 4.4301 |
| $\frac{1}{2}$ | 1.57080 | .19635 | $2\frac{7}{16}$ | 7.65763 | 4.6664 |
| $\frac{9}{16}$ | 1.76715 | .24850 | $2\frac{1}{2}$ | 7.85398 | 4.9087 |
| $\frac{5}{8}$ | 1.96350 | .30680 | $2\frac{9}{16}$ | 8.05033 | 5.1572 |
| $\frac{11}{16}$ | 2.15984 | .37122 | $2\frac{5}{8}$ | 8.24668 | 5.4119 |
| $\frac{3}{4}$ | 2.35619 | .44179 | $2\frac{11}{16}$ | 8.44303 | 5.6727 |
| $\frac{13}{16}$ | 2.55254 | .51849 | $2\frac{3}{4}$ | 8.63938 | 5.9396 |
| $\frac{7}{8}$ | 2.74889 | .60132 | $2\frac{13}{16}$ | 8.83573 | 6.2126 |
| $\frac{15}{16}$ | 2.94524 | .69029 | $2\frac{7}{8}$ | 9.03208 | 6.4918 |
| 1 | 3.14159 | .7854 | $2\frac{15}{16}$ | 9.22843 | 6.7771 |
| $1\frac{1}{16}$ | 3.33794 | .88664 | 3 | 9.42478 | 7.0686 |
| $1\frac{1}{8}$ | 3.53429 | .99402 | $3\frac{1}{16}$ | 9.62113 | 7.3662 |
| $1\frac{3}{16}$ | 3.73064 | 1.1075 | $3\frac{1}{8}$ | 9.81748 | 7.6699 |
| $1\frac{1}{4}$ | 3.92699 | 1.2272 | $3\frac{3}{16}$ | 10.0138 | 7.9798 |
| $1\frac{5}{16}$ | 4.12334 | 1.3530 | $3\frac{1}{4}$ | 10.2102 | 8.2958 |
| $1\frac{3}{8}$ | 4.31969 | 1.4849 | $3\frac{5}{16}$ | 10.4065 | 8.6179 |
| $1\frac{7}{16}$ | 4.51604 | 1.6230 | $3\frac{3}{8}$ | 10.6029 | 8.9462 |
| $1\frac{1}{2}$ | 4.71239 | 1.7671 | $3\frac{7}{16}$ | 10.7992 | 9.2806 |
| $1\frac{9}{16}$ | 4.90874 | 1.9175 | $3\frac{1}{2}$ | 10.9956 | 9.6211 |
| $1\frac{5}{8}$ | 5.10509 | 2.0739 | $3\frac{9}{16}$ | 11.1919 | 9.9678 |
| $1\frac{11}{16}$ | 5.30144 | 2.2365 | $3\frac{5}{8}$ | 11.3883 | 10.321 |
| $1\frac{3}{4}$ | 5.49779 | 2.4053 | $3\frac{11}{16}$ | 11.5846 | 10.680 |
| $1\frac{13}{16}$ | 5.69414 | 2.5802 | $3\frac{3}{4}$ | 11.7810 | 11.045 |
| $1\frac{7}{8}$ | 5.89049 | 2.7612 | $3\frac{13}{16}$ | 11.9773 | 11.416 |
| $1\frac{15}{16}$ | 6.08684 | 2.9483 | $3\frac{7}{8}$ | 12.1737 | 11.793 |

# AREAS AND CIRCUMFERENCES OF CIRCLES—continued

| Diameter Inches | Circumference Inches | Area Sq. Inches | Diameter Inches | Circumference Inches | Area Sq. Inches |
|---|---|---|---|---|---|
| $3\frac{15}{16}$ | 12.3700 | 12.177 | $5\frac{7}{8}$ | 18.4569 | 27.109 |
| 4 | 12.5664 | 12.566 | $5\frac{15}{16}$ | 18.6532 | 27.688 |
| $4\frac{1}{16}$ | 12.7627 | 12.962 | 6 | 18.8496 | 28.274 |
| $4\frac{1}{8}$ | 12.9591 | 13.364 | $6\frac{1}{8}$ | 19.2423 | 29.465 |
| $4\frac{3}{16}$ | 13.1554 | 13.772 | $6\frac{1}{4}$ | 19.6350 | 30.680 |
| $4\frac{1}{4}$ | 13.3518 | 14.186 | $6\frac{3}{8}$ | 20.0277 | 31.919 |
| $4\frac{5}{16}$ | 13.5481 | 14.607 | $6\frac{1}{2}$ | 20.4204 | 33.183 |
| $4\frac{3}{8}$ | 13.7445 | 15.033 | $6\frac{5}{8}$ | 20.8131 | 34.472 |
| $4\frac{7}{16}$ | 13.9408 | 15.466 | $6\frac{3}{4}$ | 21.2058 | 35.785 |
| $4\frac{1}{2}$ | 14.1372 | 15.904 | $6\frac{7}{8}$ | 21.5984 | 37.122 |
| $4\frac{9}{16}$ | 14.3335 | 16.349 | 7 | 21.9911 | 38.485 |
| $4\frac{5}{8}$ | 14.5299 | 16.800 | $7\frac{1}{8}$ | 22.3838 | 39.871 |
| $4\frac{11}{16}$ | 14.7262 | 17.257 | $7\frac{1}{4}$ | 22.7765 | 41.282 |
| $4\frac{3}{4}$ | 14.9226 | 17.721 | $7\frac{3}{8}$ | 23.1692 | 42.718 |
| $4\frac{13}{16}$ | 15.1189 | 18.190 | $7\frac{1}{2}$ | 23.5619 | 44.179 |
| $4\frac{7}{8}$ | 15.3153 | 18.665 | $7\frac{5}{8}$ | 23.9546 | 45.664 |
| $4\frac{15}{16}$ | 15.5116 | 19.147 | $7\frac{3}{4}$ | 24.3473 | 47 173 |
| 5 | 15.7080 | 19.635 | $7\frac{7}{8}$ | 24.7400 | 48.707 |
| $5\frac{1}{16}$ | 15.9043 | 20.129 | 8 | 25.1327 | 50.265 |
| $5\frac{1}{8}$ | 16.1007 | 20.629 | $8\frac{1}{8}$ | 25.5224 | 51.849 |
| $5\frac{3}{16}$ | 16.2970 | 21.135 | $8\frac{1}{4}$ | 25.9181 | 53.456 |
| $5\frac{1}{4}$ | 16.4934 | 21.648 | $8\frac{3}{8}$ | 26.3108 | 55.088 |
| $5\frac{5}{16}$ | 16.6897 | 22.166 | $8\frac{1}{2}$ | 26.7035 | 56.745 |
| $5\frac{3}{8}$ | 16.8861 | 22.691 | $8\frac{5}{8}$ | 27.0962 | 58.426 |
| $5\frac{7}{16}$ | 17.0824 | 23.221 | $8\frac{3}{4}$ | 27 4889 | 60.132 |
| $5\frac{1}{2}$ | 17.2788 | 23.758 | $8\frac{7}{8}$ | 27.8816 | 61.862 |
| $5\frac{9}{16}$ | 17.4751 | 24.301 | 9 | 28.2743 | 63.617 |
| $5\frac{5}{8}$ | 17.6715 | 24.850 | $9\frac{1}{8}$ | 28.6670 | 65.397 |
| $5\frac{11}{16}$ | 17.8678 | 25.406 | $9\frac{1}{4}$ | 29.0597 | 67.201 |
| $5\frac{3}{4}$ | 18.0642 | 25.967 | $9\frac{3}{8}$ | 29.4524 | 69.029 |
| $5\frac{13}{16}$ | 18.2605 | 26.535 | $9\frac{1}{2}$ | 29.8451 | 70.882 |

# AREAS AND CIRCUMFERENCES OF CIRCLES—continued

| Diameter Inches | Circumference Inches | Area Sq. Inches | Diameter Inches | Circumference Inches | Area Sq. Inches |
|---|---|---|---|---|---|
| 9⅝ | 30.2378 | 72.760 | 10⅞ | 34.1648 | 92.886 |
| 9¾ | 30.6305 | 74.662 | 11 | 34.5575 | 95.033 |
| 9⅞ | 31.0232 | 76.589 | 11⅛ | 34.9502 | 97.205 |
| 10 | 31.4159 | 78.540 | 11¼ | 35.3429 | 99.402 |
| 10⅛ | 31.8086 | 80.516 | 11⅜ | 35.7356 | 101.62 |
| 10¼ | 32.2013 | 82.516 | 11½ | 36.1283 | 103.87 |
| 10⅜ | 32.5940 | 84.541 | 11⅝ | 36.5210 | 106.14 |
| 10½ | 32.9867 | 86.590 | 11¾ | 36.9137 | 108.43 |
| 10⅝ | 33.3794 | 88.664 | 11⅞ | 37.3064 | 110.75 |
| 10¾ | 33.7721 | 90.763 | 12 | 37.6991 | 113.10 |

# DECIMAL EQUIVALENTS OF FRACTIONAL PARTS OF AN INCH

| Fractions | Decimals | Fractions | Decimals |
|---|---|---|---|
| 1/64 | 0.015625 | 33/64 | 0.515625 |
| 1/32 | 0.03125 | 17/32 | 0.53125 |
| 3/64 | 0.046875 | 35/64 | 0.546875 |
| 1/16 | 0.0625 | 9/16 | 0.5625 |
| 5/64 | 0.078125 | 37/64 | 0.578125 |
| 3/32 | 0.09375 | 19/32 | 0.59375 |
| 7/64 | 0.109375 | 39/64 | 0.609375 |
| 1/8 | 0.125 | 5/8 | 0.625 |
| 9/64 | 0.140625 | 41/64 | 0.640625 |
| 5/32 | 0.15625 | 21/32 | 0.65625 |
| 11/64 | 0.171875 | 43/64 | 0.671875 |
| 3/16 | 0.1875 | 11/16 | 0.6875 |
| 13/64 | 0.203125 | 45/64 | 0.703125 |
| 7/32 | 0.21875 | 23/32 | 0.71875 |
| 15/64 | 0.234375 | 47/64 | 0.734375 |
| 1/4 | 0.25 | 3/4 | 0.75 |
| 17/64 | 0.265625 | 49/64 | 0.765625 |
| 9/32 | 0.28125 | 25/32 | 0.78125 |
| 19/64 | 0.296785 | 51/64 | 0.796875 |
| 5/16 | 0.3125 | 13/16 | 0.8125 |
| 21/64 | 0.328125 | 53/64 | 0.828125 |
| 11/32 | 0.34375 | 27/32 | 0.84375 |
| 23/64 | 0.359375 | 55/64 | 0.859375 |
| 3/8 | 0.375 | 7/8 | 0.875 |
| 25/64 | 0.390625 | 57/64 | 0.890625 |
| 13/32 | 0.40625 | 29/32 | 0.90625 |
| 27/64 | 0.421875 | 59/64 | 0.921875 |
| 7/16 | 0.4375 | 15/16 | 0.9375 |
| 29/64 | 0.453125 | 61/64 | 0.953125 |
| 15/32 | 0.46875 | 31/32 | 0.96875 |
| 31/64 | 0.484375 | 63/64 | 0.984375 |
| 1/2 | 0.5 | 1 | 1.0 |

# DECIMAL EQUIVALENTS OF A FOOT

| In. | 0 | 1/16 | 1/8 | 3/16 | In. |
|---|---|---|---|---|---|
| 0 | 0.0000 | 0.0052 | 0.0104 | 0.0156 | 0 |
| 1 | 0.0833 | 0.0885 | 0.0937 | 0.0990 | 1 |
| 2 | 0.1667 | 0.1719 | 0.1771 | 0.1823 | 2 |
| 3 | 0.2500 | 0.2552 | 0.2604 | 0.2656 | 3 |
| 4 | 0.3333 | 0.3385 | 0.3437 | 0.3490 | 4 |
| 5 | 0.4167 | 0.4219 | 0.4271 | 0.4323 | 5 |
| 6 | 0.5000 | 0.5052 | 0.5104 | 0.5156 | 6 |
| 7 | 0.5833 | 0.5885 | 0.5937 | 0.5990 | 7 |
| 8 | 0.6667 | 0.6719 | 0.6771 | 0.6823 | 8 |
| 9 | 0.7500 | 0.7552 | 0.7604 | 0.7656 | 9 |
| 10 | 0.8333 | 0.8385 | 0.8437 | 0.8490 | 10 |
| 11 | 0.9167 | 0.9219 | 0.9271 | 0.9323 | 11 |

| In. | 1/4 | 5/16 | 3/8 | 7/16 | In. |
|---|---|---|---|---|---|
| 0 | 0.0208 | 0.0260 | 0.0313 | 0.0365 | 0 |
| 1 | 0.1042 | 0.1094 | 0.1146 | 0.1198 | 1 |
| 2 | 0.1875 | 0.1927 | 0.1979 | 0.2031 | 2 |
| 3 | 0.2708 | 0.2760 | 0.2813 | 0.2865 | 3 |
| 4 | 0.3542 | 0.3594 | 0.3646 | 0.3698 | 4 |
| 5 | 0.4375 | 0.4427 | 0.4479 | 0.4531 | 5 |
| 6 | 0.5208 | 0.5260 | 0.5313 | 0.5365 | 6 |
| 7 | 0.6042 | 0.6094 | 0.6146 | 0.6198 | 7 |
| 8 | 0.6875 | 0.6927 | 0.6979 | 0.7031 | 8 |
| 9 | 0.7708 | 0.7760 | 0.7813 | 0.7865 | 9 |
| 10 | 0.8542 | 0.8594 | 0.8646 | 0.8698 | 10 |
| 11 | 0.9375 | 0.9427 | 0.9479 | 0.9531 | 11 |

# DECIMAL EQUIVALENTS OF A FOOT—continued

| In. | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | In. |
|---|---|---|---|---|---|
| 0 | 0.0417 | 0.0469 | 0.0521 | 0.0573 | 0 |
| 1 | 0.1250 | 0.1302 | 0.1354 | 0.1406 | 1 |
| 2 | 0.2083 | 0.2135 | 0.2188 | 0.2240 | 2 |
| 3 | 0.2917 | 0.2969 | 0.3021 | 0.3073 | 3 |
| 4 | 0.3750 | 0.3802 | 0.3854 | 0.3906 | 4 |
| 5 | 0.4583 | 0.4635 | 0.4688 | 0.4740 | 5 |
| 6 | 0.5417 | 0.5469 | 0.5521 | 0.5573 | 6 |
| 7 | 0.6250 | 0.6302 | 0.6354 | 0.6406 | 7 |
| 8 | 0.7083 | 0.7135 | 0.7187 | 0.7240 | 8 |
| 9 | 0.7917 | 0.7969 | 0.8021 | 0.8073 | 9 |
| 10 | 0.8750 | 0.8802 | 0.8854 | 0.8906 | 10 |
| 11 | 0.9583 | 0.9635 | 0.9688 | 0.9740 | 11 |

| In. | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | In. |
|---|---|---|---|---|---|
| 0 | 0.0625 | 0.0677 | 0.0729 | 0.0781 | 0 |
| 1 | 0.1458 | 0.1510 | 0.1563 | 0.1615 | 1 |
| 2 | 0.2292 | 0.2344 | 0.2396 | 0.2448 | 2 |
| 3 | 0.3125 | 0.3177 | 0.3229 | 0.3281 | 3 |
| 4 | 0.3958 | 0.4010 | 0.4063 | 0.4115 | 4 |
| 5 | 0.4792 | 0.4844 | 0.4896 | 0.4948 | 5 |
| 6 | 0.5625 | 0.5677 | 0.5729 | 0.5781 | 6 |
| 7 | 0.6458 | 0.6510 | 0.6563 | 0.6615 | 7 |
| 8 | 0.7292 | 0.7344 | 0.7396 | 0.7448 | 8 |
| 9 | 0.8125 | 0.8177 | 0.8229 | 0.8281 | 9 |
| 10 | 0.8958 | 0.9010 | 0.9063 | 0.9115 | 10 |
| 11 | 0.9792 | 0.9844 | 0.9896 | 0.9948 | 11 |

# AMERICAN STEAM, WATER, AND GAS PIPES

| Size of Pipe Inches | Actual Outside Diameter Inches | Actual Inside Diameter Inches | Number of Threads per Inch of Screw |
|---|---|---|---|
| ⅛ | 0.405 | 0.270 | 27 |
| ¼ | 0.54 | 0.364 | 18 |
| ⅜ | 0.675 | 0.494 | 18 |
| ½ | 0.84 | 0.623 | 14 |
| ¾ | 1.05 | 0.824 | 14 |
| 1 | 1.315 | 1.048 | 11½ |
| 1¼ | 1.66 | 1.380 | 11½ |
| 1½ | 1.9 | 1.611 | 11½ |
| 2 | 2.375 | 2.067 | 11½ |
| 2½ | 2.875 | 2.468 | 8 |
| 3 | 3.5 | 3.067 | 8 |
| 3½ | 4 | 3.548 | 8 |
| 4 | 4.5 | 4.026 | 8 |
| 4½ | 5 | 4.508 | 8 |
| 5 | 5.563 | 5.045 | 8 |
| 6 | 6.625 | 6.065 | 8 |
| 7 | 7.625 | 7.023 | 8 |
| 8 | 8.625 | 7.982 | 8 |

# WHITWORTH GAS THREADS

| Size In. | Diameter at Top of Thread | Diameter at Bottom of Thread | No. of Threads per In. |
|---|---|---|---|
| ⅛ | 0.3825 | 0.3367 | 28 |
| ¼ | 0.518 | 0.4506 | 19 |
| ⅜ | 0.6563 | 0 5889 | 19 |
| ½ | 0.8257 | 0.7342 | 14 |
| ⅝ | 0.9022 | 0.8107 | 14 |
| ¾ | 1.041 | 0.9495 | 14 |
| ⅞ | 1.189 | 1.0975 | 14 |
| 1 | 1.309 | 1.1925 | 11 |
| 1⅛ | 1.492 | 1.3755 | 11 |
| 1¼ | 1.65 | 1.5335 | 11 |
| 1⅜ | 1.745 | 1.6285 | 11 |
| 1½ | 1.8825 | 1.765 | 11 |
| 1⅝ | 2.021 | 1.905 | 11 |
| 1¾ | 2.16 | 2.042 | 11 |
| 1⅞ | 2.245 | 2.1285 | 11 |
| 2 | 2.347 | 2.2305 | 11 |
| 2¼ | 2.5875 | 2.471 | 11 |
| 2½ | 3.0013 | 2.8848 | 11 |
| 2¾ | 3.247 | 3.1305 | 11 |
| 3 | 3.485 | 3.3685 | 11 |
| 3¼ | 3.6985 | 3.582 | 11 |
| 3½ | 3.912 | 3.7955 | 11 |
| 3¾ | 4.1255 | 4.009 | 11 |
| 4 | 4.339 | 4.223 | 11 |

# WHITWORTH GAS THREADS

## APPROXIMATE EQUIVALENT SIZES

| Size In. | Diameter at Top of Thread | Diameter at Bottom of Thread | No. of Threads per In. |
|---|---|---|---|
| 1/8 | 3/8 | 21.5/64 | 28 |
| 1/4 | 33/64 | 29/64 | 19 |
| 3/8 | 21/32 | 19/32 | 19 |
| 1/2 | 53/64 | 47/64 | 14 |
| 5/8 | 29/32 | 13/16 | 14 |
| 3/4 | 1 1/32 | 15/16 | 14 |
| 7/8 | 1 3/16 | 1 3/32 | 14 |
| 1 | 1 5/16 | 1 3/16 | 11 |
| 1 1/8 | 1 31.5/64 | 1 3/8 | 11 |
| 1 1/4 | 1 21/32 | 1 17/32 | 11 |
| 1 3/8 | 1 3/4 | 1 5/8 | 11 |
| 1 1/2 | 1 7/8 | 1 49/64 | 11 |
| 1 5/8 | 2 1/64 | 1 29/32 | 11 |
| 1 3/4 | 2 5/32 | 2 3/64 | 11 |
| 1 7/8 | 2 1/4 | 2 1/8 | 11 |
| 2 | 2 11/32 | 2 15/64 | 11 |
| 2 1/4 | 2 19/32 | 2 15/32 | 11 |
| 2 1/2 | 3 | 2 7/8 | 11 |
| 2 3/4 | 3 1/4 | 3 1/8 | 11 |
| 3 | 3 31/64 | 3 23.6/64 | 11 |
| 3 1/4 | 3 45/64 | 3 37/64 | 11 |
| 3 1/2 | 3 29/32 | 3 51/64 | 11 |
| 3 3/4 | 4 1/8 | 4 | 11 |
| 4 | 4 11/32 | 4 7/32 | 11 |

# REDUCTION OF DIAMETER OF BOLTS, ETC., DUE TO WHITWORTH THREADS

| No. of Threads per In. | Reduction in Diameter | No. of Threads per In. | Reduction in Diameter | No. of Threads per In. | Reduction in Diameter |
|---|---|---|---|---|---|
| | In. | | In. | | In. |
| 1 | 1.2806 | 4½ | 0.2846 | 14 | 0.0915 |
| 2 | 0.6403 | 5 | 0.2561 | 15 | 0.0854 |
| 2½ | 0.5123 | 6 | 0.2134 | 16 | 0.0800 |
| 2⅝ | 0.4879 | 7 | 0.1829 | 17 | 0.0753 |
| 2¾ | 0.4657 | 8 | 0.1600 | 18 | 0.0711 |
| 2⅞ | 0.4454 | 9 | 0.1423 | 19 | 0.0674 |
| 3 | 0.4268 | 10 | 0.1281 | 20 | 0.0640 |
| 3¼ | 0.3940 | 11 | 0.1164 | 24 | 0.0534 |
| 3½ | 0.3659 | 12 | 0.1067 | 28 | 0.0457 |
| 4 | 0.3201 | 13 | 0.0985 | 40 | 0.0320 |

Reduction = 1.280654 ÷ number of threads per inch.

# HYDRAULIC EQUIVALENTS

1 imperial gallon = 277.274 cubic inches.

1 imperial gallon = 0.16045 cubic foot.

1 imperial gallon = 10 lb.

A cubic foot of sea water = 64.00 lb.

A cubic inch of sea water = 0.037037 lbs.

A cubic foot of water = 62.32 lb.

A cubic inch of water = 0.03616 lb.

A cylindrical foot of water = 48.96 lb.

A cylindrical inch of water = 0.0284 lb.

A column of water 12 in. long 1 in. square = 0.434 lb.

## HYDRAULIC EQUIVALENTS—continued

A column of water 12 in. long 1 in. diameter = 0.340 lb.

The capacity of a 12 in. cube = 6.232 gallons.

The capacity of a 1 in. square 1 ft. long = 0.0434 gallon.

The capacity of a 1 ft. diameter 1 ft. long = 4.896 gallons.

The capacity of a cylinder in gallons 1 yd. long = 0.1 diameter squared.

The capacity of a 1 in. diameter 1 ft. long = 0.034 gallon.

The capacity of a cylindrical inch = 0.002832 gallon.

The capacity of a cubic inch = 0.003606 gallon.

The capacity of a sphere 12 in. diameter = 3.263 gallons.

The capacity of a sphere 1 in. diameter = 0.00188 gallon.

1 imperial gallon = 1.2 United States gallon.

1 imperial gallon = 4.543 litres of water.

1 United States gallon = 231.0 cubic inches.

1 United States gallon = 0.83 imperial gallon.

1 United States gallon = 3.8 litres of water.

1 cubic foot of water = 6.232 imperial gallons.

1 cubic foot of water = 7.476 United States gallons.

1 cubic foot of water = 28.375 litres of water.

1 litre of water = 0.22 imperial gallon.

1 litre of water = 0.264 United States gallon.

1 litre of water = 61.0 cubic inches.

1 litre of water = 0.0353 cubic foot.

# METHOD OF MEASUREMENT FOR ROUNDS AND FLATS IN METALS

The table below shows thousandths of an inch compared with the Birmingham Wire Gauge.

| Inches | Birm. Gauge | Inches | Birm. Gauge | Inches | Birm. Gauge |
|---|---|---|---|---|---|
| .002 | | .032 | 21 | .095 | 13 |
| .004 | 36 | .036 | 20 | .100 | |
| .006 | 35 | .040 | 19 | .110 | 12 |
| .008 | 33 | .045 | | .125 | 11 |
| .010 | 31 | .050 | 18 | .135 | 10 |
| .012 | 30 | .055 | 17 | .150 | 9 |
| .014 | 28 | .060 | | .165 | 8 |
| .016 | 27 | .065 | 16 | .180 | 7 |
| .018 | 26 | .070 | 15 | .200 | 6 |
| .020 | 25 | .075 | | .220 | 5 |
| .022 | 24 | .080 | 14 | .240 | 4 |
| .025 | 23 | .085 | | .250 | 3 |
| .028 | 22 | .090 | | | |

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